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DESCRIPTION

LIQUID DISCHARGE HEAD

TECHNICAL FIELD

The present invention relates to a liquid discharge head configured to discharge liquid and, more specifically, relates to an inkjet recording head (hereinafter referred to as 'recording head') configured to use heat radiated from heating resistors to discharge ink onto a recording medium.

BACKGROUND ART

A known recording head described in Japanese Patent Laid-Open No. 2002-79672 includes two nozzle rows, each row including a plurality of nozzles aligned at regular pitch, and an ink inlet provided between the nozzle rows. By providing nozzles on both sides of the ink inlet so that nozzles in one nozzle row are offset by a half pitch from the nozzles in the other nozzle row, the nozzle density of in a known recording head having such a structure is two times the nozzle density of a recording head including only one nozzle row.

Fig. 1 is a perspective plan view illustrating the inlets and their periphery of a known recording head. As illustrated in Fig. 1, on both sides of an

ink inlet 1500, a plurality of outlets 1100 are aligned at a predetermined pitch in the longitudinal direction of the ink inlet 1500 (i.e., the vertical direction in the drawing). The ink inlet 1500 communicates with nozzles that each includes one of the outlets 1100 and an ink channel 1300. In this way, ink is supplied from the ink inlet 1500 to each of the outlets 1100.

More specifically, the ink channel 1300 is constituted of a pressure chamber 1302 that includes a recording element 1400 having a heating resistor and a transporting path 1301 for supplying ink to the pressure chamber 1302. The pressure chamber 1302 is a space where discharge energy is applied to ink. The pressure chamber 1302 must be large enough to enable appropriate discharge of ink from the outlet 1100.

Japanese Patent Laid-Open No. 2002-374163 describes a recording head including recording elements each having a heating resistor, a driver (for example, a transistor) for driving the recording element, and a logic circuit for selectively driving the driver in accordance with image data.

A commercialized version of the recording head shown in Fig. 1 has a nozzle density of 1,200 dots per inch (dpi) per color (i.e., the nozzle density for each nozzle row is 600 dpi) and an ink droplet

volume of 2 picoliters (pl) for each ink droplet discharged from the outlets 1100. However, in order to produce high quality images, a recording head capable of discharging droplets having even smaller volumes is in need. To obtain such a recording head, the nozzle density may be increased while the volume of the droplets discharged from the nozzles is decreased. More specifically, for example, the discharge amount of a recording head may be less than 2 pl and the nozzle density of two nozzle rows included in the recording head may be 2,400 dpi, wherein the nozzle density of each nozzle row is 1,200 dpi.

However, since the outlets 1100 of the recording head having the above-described nozzle density are aligned in rows along the longitudinal direction of the ink inlet 1500, it becomes difficult to maintain the thickness of the walls between each ink channel 1300. As a result, the reliability of the recording head is reduced.

To solve this problem, a recording head according to an embodiment of the present invention includes nozzle rows having outlets 1100 arranged in a staggered pattern, as illustrated in Fig. 2. The recording head shown in Fig. 2 is structured so that the distances from the ink inlet 1500 to adjacent outlets 1100 alternate. The ink channels 1300

corresponding to the outlets 1100 disposed closer to the ink inlet 1500 include transporting paths 1301 and pressure chambers 1302. Ink channels 1305 corresponding to the outlets 1100 disposed further away from the ink inlet 1500 include transporting paths 1306, wherein each of the transporting paths 1306 are interposed between adjacent pressure chambers 1302.

When the outlets 1100 are disposed in a staggered pattern with respect to the ink inlet 1500, as described above, the lengths of transporting paths 1301 and the transporting paths 1306 differ. Since the nozzle density is expected to be high (i.e., the pitch of the nozzles is expected to be small), the difference in the lengths of the transporting paths causes a significant difference in the channel resistance at the rear area of the heating resistors. Furthermore, the heating resistors disposed closer to the inlet 1500 are shaped as rectangles extending in the longitudinal direction of the channels so as to increase their heating areas. The rectangular shape of the heating resistors causes the difference in the lengths of the transporting paths to become even more prominent.

This difference in the lengths of the transporting paths causes a difference in the refilling speed. It is difficult to obtain a

satisfactory refilling speed in the liquid channels corresponding to the heating resistors disposed further away from the inlet 1500.

The difference in the channel resistance also cause a difference in the discharge performance of the outlets. A significant difference in the discharge performance of each outlet may cause a decrease in image quality.

Such problems are not only typical to recording heads configured to discharge droplets of the same volume from the nozzles. For example, a recording head including both nozzles for discharging droplets of a relatively large volume and nozzles for discharging droplets of a relatively small volume may also have the same problems when the nozzle density is increased. These problems are not limited to recording heads configured to carry out recording by discharging ink. The same problems may be experienced also in liquid discharge heads used in the technical fields other than recording (e.g., color filter manufacturing and circuit pattern drawing) that discharge liquid using recording elements including heating resistors.

DISCLOSURE OF INVENTION

The present invention is configured on the basis to solve the above-described problems and

provides a liquid discharge head including outlets disposed in a staggered pattern so that the distances from the outlets to an inlet differ in such a manner that the outlets disposed further away from the inlet are also capable of stably discharging liquid.

A liquid discharge head according to an embodiment of the present invention includes a plurality of outlets for discharging liquid, liquid channels that communicate with the corresponding outlets, an inlet, provided on a substrate and configured to supply liquid to the liquid channels, recording elements disposed opposite to the plurality of outlets include heating resistors provided on the substrate. The outlets include first outlets disposed relatively closer to the inlet and second outlets disposed relatively further from the inlet and are arranged in a staggered pattern in which the first outlets and the second outlets are disposed alternately on at least one side of the inlet. The recording elements include first recording elements corresponding to the first outlets and second recording elements corresponding to the second outlets. An aspect ratio based on the flow direction of the liquid channels of the first recording elements is greater than the aspect ratio of the second recording elements.

Since the second recording elements

corresponding to the second outlets disposed further away from the inlet included in the liquid discharge head according to an embodiment of the present invention are substantially square, the second recording elements are capable of applying discharge energy more efficiently to the liquid compared to rectangular recording elements. As a result, the second outlets are also capable of stably discharging liquid.

Further features of the present invention will become apparent from the following description of exemplary embodiments (with reference to the attached drawings).

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective plan view of a known recording head.

Fig. 2 is a perspective plan view of a recording head including outlets disposed in a staggered pattern.

Fig. 3 is a perspective schematic view of a recording head according to a first embodiment.

Fig. 4 is a partial perspective plan view of an outlet surface of the recording head shown in Fig. 3 and illustrates recording elements and their periphery.

Fig. 5 is an exploded perspective plan view of

two types of ink channels and their periphery included in the recording head shown in Fig. 4.

Figs. 6A, 6B and 6C illustrate details of a recording element, wherein Fig. 6A is a top view of a wiring pattern configuring the recording element and Figs. 6B and 6C illustrate cross-sectional views taken along lines VIB-VIB and VIC-VIC, respectively, shown in Fig. 6A.

Fig. 7 is a block diagram of the circuitry in which a driving pulse is divided.

Fig. 8 is a block diagram illustrating the circuitry in which a driving voltage is divided.

Fig. 9 is a block diagram illustrating the circuitry in which both a driving pulse and a driving pulse are divided.

Figs. 10A and 10B are perspective plan views of a recording head according to a second embodiment.

BEST MODE FOR CARRYING OUT THE INVENTION

Now, embodiments of the present invention will be described with reference to the drawings.

First Embodiment

Fig. 3 is a perspective schematic view of a recording head according to a first embodiment.

As shown in Fig. 3, a recording head 101 includes a silicon (Si) substrate 110 (semiconductor substrate) and a channel-forming member 111. On the

upper surface of the Si substrate 110, a plurality of recording elements 400 having, for example, heating resistors is provided. The channel-forming member 111 covers the recording elements 400 on the Si substrate 110. Although the present invention is characterized by the recording elements 400 and their peripheral structure, first, the overall structure of the recording head 101 will be briefly described.

The Si substrate 110 includes a common liquid chamber 112 penetrating through the Si substrate 110. On the upper surface of the common liquid chamber 112, an opening is provided so as to function as a longitudinal ink inlet 500. Although Fig. 3 only shows the recording elements 400 on one side of the ink inlet 500, the recording elements 400 are provided along the ink inlet 500 on both sides. The recording elements 400 include heating resistors, whose detailed structure will be described below, configured to radiate heat when a voltage is applied from the outside via electrical wiring not shown in the drawing. By heating the ink, discharge energy is applied to the ink.

In Fig. 3, the recording elements 400 are aligned along the longitudinal direction of the ink inlet 500. However, as illustrated in Fig. 4, the recording elements 400 are actually disposed in a staggered pattern, as described below.

The channel-forming member 111 includes a plurality of outlets 100 configured to discharge ink. Each of the outlets 100 is disposed opposite to each of the corresponding recording elements 400. The outlets 100 constitute of two outlet groups 900 provided on both sides of the ink inlet 500. A plurality of ink channels 300 configured to guide ink from the ink inlet 500 to the outlets 100 are interposed between the channel-forming member 111 and the upper surface of the Si substrate 110.

The recording head 101 having such a structure is aligned and fixed on an ink supplying member 150 having a ink channel (not shown) for supplying ink to the common liquid chamber 112 in the Si substrate 110. When the recording head 101 is at use, it operates as described below. First, a voltage applied to the recording elements 400 from outside via electrical wiring (not shown) causes the recording elements 400 including heating resistors to radiate heat. The thermal energy causes the ink inside the ink channels 300 to boil. The bubbles generated by this boiling pushes the ink in the ink channels 300 out from the outlets 100 as ink droplets. The recording head 101 having such a structure carries out the above-described operation while the upper surface of the channel-forming member 111, i.e., the outlet surface, opposes a recording medium, such as paper. As a

result, the discharged ink droplets are applied to the recording medium to form an image on the recording medium.

Next, the structure of the recording elements 400 and their periphery characterizing the present invention will be described with reference to Figs. 4 and 5. Fig. 4 is a partial perspective plan view of the outlet surface of the recording head 101, shown in Fig. 3, and illustrates the recording elements 400 and their periphery in the recording head 101. Fig. 5 is an exploded perspective plan view of two types of ink channels and their periphery included in the recording head 101 shown in Fig. 4.

As illustrated in Fig. 5, the above-described outlet groups 900 include an outlet group 900a and an outlet group 900b, wherein the ink inlet 500 is interposed between the outlet groups 900a and 900b. The outlet groups 900a and 900b basically have the same structure but are offset a half pitch (p/2) in the longitudinal direction of the ink inlet 500 (i.e., the vertical direction in the drawing). Below, outlet group 900a is described as an example of the outlet groups 900. Hereinafter, 'outlet group 900a' may be simply referred to as 'outlet group 900'.

The outlet group 900 includes first outlets 100a disposed closer to the ink inlet 500 and second outlets 100b disposed further away from the ink inlet

500. Each of the first outlets 100a and each of the second outlets 100b are provided alternately along the vertical direction in the drawing. In other words, the outlets 100a and 100b are disposed in a staggered pattern. The first outlets 100a and the second outlets 100b are disposed at a pitch p with the same intervals in the vertical direction in the drawing. The outlets 100a and 100b (or collectively referred to as 'outlets 100') are circular and have the same size.

The pitch p is set so that the outlet density of the outlet group 900 is 1,200 dpi. Since, as described above, the outlet groups 900a and 900b are offset by a half pitch (p /2), the resolution of the entire recording head 101 is 2,400 dpi. According to this embodiment, the volume of each ink droplet discharged from each of the outlets 100 is 1 pl. The sizes of the components and the ink droplet volume suitable for obtain the above-mentioned resolution will be described in detail below.

Since the outlets 100a and 100b are disposed in a staggered pattern, as described above, the ink channels 300 and the recording elements 400 are also disposed in a staggered pattern corresponding to the outlets 100a and 100b.

More specifically, the ink channels 300, as shown in Fig. 4, include first ink channels 300a

having a relatively short channel length and being connected to the corresponding first outlets 100a and second ink channels having a relatively long channel length 300b and being connected to the corresponding second outlets 100b. As shown in Fig. 5, the ink channels 300a and 300b include pressure chambers 302a and 302b, respectively, and transporting paths 301a and 301b, respectively. The pressure chambers 302a and 302b are provided in areas including the outlets 100. The transporting paths 301a and 301b are configured to transport ink to the pressure chambers 302a and 302b, respectively. In Fig. 5, the width of the area upstream of the transporting paths 301b is greater than the width of the other areas of the transporting paths 301b. However, the structure of the transporting paths 301b is not limited.

The pressure chambers 302a and 302b include first recording elements 400a and second recording elements 400b, respectively. The shape of the first recording elements 400a differs from the shape of the second recording elements 400b. To achieve satisfactory discharge from the outlets 100a and 100b, some space is provided between the outside edge of recording elements 400a and 400b and the inner walls of the pressure chambers 302a and 302b. The outlets 100a and 100b are disposed so that they are positioned substantially in the center of the

recording elements 400a and 400b, respectively.

As described above, the transporting paths 301a and 301b may have small widths (W_{300a} and W_{300b}, respectively) compared to the widths of the pressure chambers 302a and 302b, respectively, so long as ink is stably supplied to the pressure chambers 302a and 302b. In this embodiment, since the outlets 100a and 100b are disposed in a staggered pattern, the pressure chambers 302a and the pressure chambers 302b do not align in the vertical direction in the drawing. In this way, the outlets 100a and 100b are disposed in a highly dense manner while maintaining a satisfactory thickness of the walls of the transporting paths 301a and 301b. In particular, the outlets 100a and 100b can be disposed in a highly dense manner when the width W_{300b} of the transporting paths 301b is substantially the same or smaller than the width W_{400a} of the first recording elements 400a.

Next, the detailed structure of the recording elements 400a and 400b including heating resistors is described with reference to Figs. 6A, 6B and 6C. Fig. 6A is a top view of a wiring pattern configuring the recording elements 400a and 400b. Figs. 6B and 6C are cross-sectional views taken along lines VIB-VIB and VIC-VIC, respectively, in Fig. 6A.

As illustrated in Figs. 6A, 6B and 6C, each of the recording elements 400a and 400b is formed by

removing sections of a wiring layer 702 stacked on a resistive layer 700. When a voltage is applied to the wiring layer 702, the sections removed from the wiring layer 702 on the resistive layer 700 function as resistors and generate heat. Patterning of the recording elements 400a and 400b having such a structure is easy since the area functioning as resistors can be easily changed by merely changing the pattern of the resistive layer 700 and the wiring layer 702. In this way, the heating value of the recording elements 400a and 400b can be easily adjusted. As illustrated in Figs. 6A, 6B and 6C, the first recording elements 400a that are formed close to the ink inlet 500 are formed by removing sections from the wiring layer 702 so that rectangular areas of the resistive layer 700 are exposed. The second recording elements 400b that are formed further away from the ink inlet 500 are formed by removing sections from the wiring layer 702 so that substantially square areas of the resistive layer 700 are exposed.

When the outlets 100a and 100b are disposed in a highly dense manner in a staggered pattern, the length of the second ink channels 300b becomes relatively longer. As a result, the ink refilling time may be extended and/or the discharge from the second outlets 100b may become unstable. Therefore,

according to this embodiment, the discharge from the second outlets 100b is stabilized by taking two different countermeasures as described below. The first countermeasure taken is to set the area defining each of the second recording elements 400b smaller than the area defining each of the first recording elements 400a. Another countermeasure taken is to set the aspect ratio of the outer shape of the second recording elements 400b smaller than the aspect ratio of the outer shape of the first recording elements 400a so that the second recording elements 400b is substantially a square.

These countermeasures will be described in detail below.

To maintain the discharge balance between the first outlets 100a and the second outlets 100b, the discharge performance of the nozzles provided at the further away from the ink inlet 500 (i.e., the nozzles including the second outlets 100b) may be improved. Furthermore, the aspect ratio of each of the heating resistors may be set close to 1 (i.e., the shape of the heat resistor may be substantially a square). The discharge is stabilized by reducing the aspect ratio of each of the second recording elements 400b because of the following reason. For the recording elements 400a and 400b, the temperature at their peripheral areas is lower than the temperature

at their centers. Thus, the peripheral areas of the recording elements 400a and 400b do not contribute to the boiling of the ink. Therefore, when the rectangular first recording elements 400a are compared with the substantially square second recording elements 400b, the area contributing to the boiling of the ink with respect to the entire area of the recording element is relatively larger for the second recording elements 400b compared to the first recording elements 400a. In other words, the second recording elements 400b are capable of effectively transferring discharge energy to the ink.

To obtain an aspect ratio of substantially one by reshaping a rectangular heating resistor, either the width of the heating resistor may be increased or the length of the heating resistor may be reduced. In this embodiment, the nozzle density is predetermined. Therefore, the width of the heating resistors may not be increased due to a lack of space, but the length of the heating resistor may be reduced. As a result, the area of heating resistors disposed further away from the ink inlet 500 is reduced so that the area of the second recording elements 400b is smaller than the area of the first recording elements 400a.

The recording head 101 according to this embodiment includes the outlets 100 that have the

same size and discharge droplets of the same volume. Since the discharge amount of the recording head 101 is small, the absolute refilling frequency is rarely reduced since the refill amount of the nozzles disposed further away from the ink inlet 500 is small.

If the shape of the second recording elements 400b is substantially square, the centers of the second recording elements 400b can be disposed relatively closer to the ink inlet 500, as shown in Fig. 4, compared to when the shape of the second recording elements 400b is rectangular. In this way, refilling becomes easier.

Detailed sizes of the components according to this embodiment are described below.

As an exemplary size of a component described above, the area of the opening of each of the outlets 100 may be 70 μm^2. Furthermore, the width W_{400a} and the length of the first recording elements 400a may be 10 μm and 28 μm, respectively, and the width W_{400b} and the length of the first recording elements 400b may be 14 μm and 18 μm, respectively. In other words, the first recording elements 400a may have an area of 280 μm^2, and second recording elements 400b may have an area of 252 μm^2, wherein the area of each of the first recording elements 400a is larger than the area of each of the second recording elements 400b.

A good discharge balance may be maintained

between the first and second recording elements 400a and 400b of the recording head 101 according to this embodiment having a nozzle density of 1,200 dpi or more and including the outlets 100 of the same shape capable of discharging droplets of the same volume if the following formulas are satisfied (where the aspect ratio is based on the direction of the channel):

0.95>area of second recording element/area of first recording element>0.6 (1)

and

aspect ratio of second recording element/aspect ratio of first recording element<0.95 (2)

As described above, in this embodiment, discharge of the second recording elements 400b is carried out more efficiently than discharge of the first recording elements 400a. As a result, the discharge characteristics are the same for all of the outlets 100 regardless of the difference in the lengths of the ink channels 300a and 300b.

In this embodiment, a sufficient amount of energy may be supplied to the recording elements 400a and 400b to adequately drive the recording elements 400a and 400b.

More specifically, since the recording elements 400a and 400b include heating resistors, the heating value of the recording elements 400a and 400b is

determined in accordance with the resistance and the heating value per unit area of the material of the resistive layer 700. The resistance of the recording elements 400a and 400b is determined in accordance with the shape of the recording elements 400a and 400b. The resistance of the recording elements 400a and 400b having the structure shown in Figs. 6A, 6B and 6C becomes greater as the length of the recording elements 400a and 400b in the flow direction of the electrical current (i.e., the horizontal direction in Figs. 6A, 6B and 6C or the width of the ink inlet 500) increases. In other words, resistance becomes greater as the ratio of vertical length to the horizontal length of the recording elements 400a and 400b becomes greater, where the vertical length is equal to the width of the ink inlet 500. Therefore, when the same driving voltage and the same driving pulse are applied to both the recording elements 400a and 400b, the amount of energy supplied to the recording elements 400a and 400b may be excess or short. As a result, the discharge performance of the recording elements 400a and 400b will vary. To apply the same driving pulse to the both recording elements 400a and 400b, both the recording elements 400a and 400b are driven based on the same driving time.

The recording head 101 according to this embodiment can appropriately drive the recording

elements 400a and 400b by dividing components, such as logic circuits configured to determine the driving pulse of the recording elements or by dividing a driving voltage that supplies electrical power to the driving devices.

An exemplary circuitry employed in the recording head 101 according to this embodiment will be described with reference to Figs. 7, 8, and 9. Fig. 7 is a block diagram illustrating a circuitry in which a driving pulse is divided. Fig. 8 is a block diagram illustrating a circuitry in which a driving voltage is divided. Fig. 9 is a block diagram illustrating a circuitry in which both a driving pulse and a driving voltage are divided.

Structure for Dividing Driving Pulse

The circuitry shown in Fig. 7 includes a processing block 630, a plurality of terminals 620a to 620n, an electrical power supply terminal 610, a ground (GND) terminal 611, power transistors (driver) 650, a first driving time determining signal terminal 600, a second driving time determining signal terminal 601, first AND circuits 640a, and second AND circuits 640b. The processing block 630 is configured to control processing of various data and time-division driving. The plurality of terminals 620a to 620n are connected to the processing block 630 and send clock (CLK) data, image data, and data

related to time-division driving to the processing block 630. The electrical power supply terminal 610 supplies a driving voltage to the recording elements 400a and 400b. The circuitry includes power transistors (driver) 650 is configured to switch the power distribution to each of the recording elements 400a and 400b. The first driving time determining signal terminal 600 determines the driving time of the first recording elements 400a. The second driving time determining signal terminal 601 determines the driving time of the first recording elements 400b. The outputs of the first AND circuits 640a and the second AND circuits 640b are connected to the power transistor 650.

A signal processed at the processing block 630 is sent to first inputs of the AND circuits 640a and 640b. A signal from the first driving time determining signal terminal 600 is sent to a second input of the first AND circuits 640a, and a signal from the second driving time determining signal terminal 601 is sent to second input of the second AND circuits 640b.

In a circuit configured as described above, the driving time determining signal terminal is divided into the driving time determining signal terminals 600 and 601 corresponding to the recording elements 400a and 400b, respectively. The recording elements

400a and 400b are driven in accordance with the logical product (AND) of a driving pulse from the driving time determining signal terminal 600 or 601 and recording data from the processing block 630. Accordingly, the recording elements 400a and 400b are driven based on different driving times (i.e., different driving pulses) sent from the driving time determining signal terminals 600 and 601, respectively. In this way, the recording elements 400a and 400b can be operated based on appropriate driving times that enable satisfactory discharge.

Structure for Dividing Driving Voltage

In the circuitry shown in Fig. 8, the driving voltage (power supply voltage) supplied to the recording elements 400a and 400b is divided. In the circuitry shown in Fig. 8, the electrical power supply terminal 610 included in the circuitry shown in Fig. 7 is replaced by two electrical power supply terminals 610a and 610b. The first electrical power supply terminal 610a supplies a driving voltage to the first recording elements 400a, and the second electrical power supply terminal 610b supplies a driving voltage to the first recording elements 400b. In the circuitry shown in Fig. 8, the driving time determining signal terminals 600 and 601 included in the circuitry shown in Fig. 7 are replaced by a common driving time determining signal terminal 602.

The other components included in the circuitry shown in Fig. 8 are the same as those included in the circuitry shown in Fig. 7. The components shown in Fig. 8 having the same function as those shown in Fig. 7 are represented by the same reference numerals.

In a circuit configured in this way, separate driving voltages are supplied from the electrical power supply terminal 610a and 610b to the recording elements 400a and 400b, respectively. In this way, the recording elements 400a and 400b can be operated based on appropriate driving times that enable satisfactory discharge.

Structure for Dividing Driving Pulse and Driving Voltage

The circuitries shown in Figs. 7 and 8 have been described above. These two types of circuitries can be combined as illustrated in Fig. 9. The circuitry shown in Fig. 9 includes two driving time determining signal terminals 600 and 601 and two electrical power supply terminals 610a and 610b. By using the two driving time determining signal terminals 600 and 601 and two electrical power supply terminals 610a and 610b, even more precise drive control is possible.

Second Embodiment

Figs. 10A and 10B are a perspective plan view of an outlet surface of a recording head according to

a second embodiment and illustrate recording elements and their periphery.

The recording head illustrated in Fig. 10A includes an outlet group 900b on one side of an ink inlet 500. The outlet group 900b has a nozzle density of 1,200 dpi, which is the same nozzle density as the above-described recording head 101 according to the first embodiment. On the other side of the ink inlet 500, an outlet group 900c including outlets 100c, whose openings are relatively large in area, is provided. The outlets 100c are aligned along the longitudinal direction of the ink inlet 500 and receive ink through corresponding ink channels 300c having a relatively wide width. The recording elements 400c disposed in the ink channels 300c are substantially square and their surface area is greater than the recording elements 400a and 400b according to the first embodiment.

According to the recording head shown in Fig. 10A, when high resolution is required, the outlet group 900b can be mainly used, whereas, when high-speed recording is required at a lower resolution, the outlet group 900c can be mainly used. In this way, the recording head can be used for both high-quality recording and high-speed recording.

The recording head illustrated in Fig. 10B is the same as the recording head 101 except that third

outlets 100d, third recording elements 400d, and third ink channels 300d are provided instead of the second outlets 100b, the second recording elements 400b, and the second ink channels 300b, respectively.

The third outlets 100d are smaller than the second outlets 100b, and the third recording elements 400d are smaller than the second recording elements 400b. The shape of the third outlets 100d is circular, and the shape of the third recording elements 400d is substantially square.

When a recording head has outlets of different diameters in order to perform gradation recording, the recording elements 400d (heating resistors) corresponding to the outlets 100d having small diameters (i.e., the small outlets) are smaller than the recording elements 400a corresponding to the outlets 100a having larger diameters (i.e., the large outlets). For the aspect ratio of the heating resistor disposed in the recording elements 400d further away from the ink inlet 500 to be substantially one, the outlet diameter of the outlets 100d disposed further away from the ink inlet 500 may be small. The refill amount of the ink channels 300d corresponding to the small outlets 100d is less than the refill amount of the ink channels 300a corresponding to the large outlets 100a so long as the discharge frequencies are the same for all

nozzles. Accordingly, by having the small outlets 400d disposed further away from the ink inlet 500, the refill frequency of the entire recording head can be improved.

According to the recording head shown in Fig. 10B, although the discharge amount from the third outlets 100d is less than the discharge amount from the first outlets 100a according to the first embodiment, since the recording elements 400d are substantially square, the discharge from the third outlets 100d is stabilized in a similar manner as the above-described recording head 101.

As shown in Fig. 10B, details of the discharge amount from nozzles with different diameters disposed alternately on the recording head according to this embodiment will be described.

To perform gradation recording, the contrast between the image recorded by the large outlets 100a discharging a large discharge amount and the small outlets 100d discharging a small discharge amount may be twofold. If the pitch is set so that the nozzle density is 1,200 dpi, the distance between adjacent nozzles is 21 μm. Within this distance of 21 μm, an ink channel 300d corresponding to the outlet 100d disposed further away from the ink inlet 500, the recording element 400a disposed closer to the ink inlet 500, and walls separating the ink channel 300d

and the recording element 400a are provided.

The discharge amount also depends on the area of the heating resistor. However, since the width of the heating resistor is limited because of the above-described restrictions, the maximum discharge amount of the large outlets 100a disposed closer to the ink inlet 500 is about 2 pl. The maximum discharge amount of the small outlets 100d disposed further away from the ink inlet 500 is about 1 pl and the preferable amount of the small outlets 100d is about 0.6pl because of the width of the ink channel 300d to the small outlet 100d. If the discharge amount of the large outlets 100a disposed closer to the ink inlet 500 is set to about 1 pl, the discharge amount of the small outlets 100d disposed further away from the ink inlet 500 may be less than about 0.6 pl. However, if the discharge amount is significantly small, the accuracy of the droplets landing at target areas is reduces. Therefore, a discharge amount of about 0.6 pl is appropriate. Accordingly, in this embodiment, if the discharge amount of the small outlets 100d disposed further away from the ink inlet 500 is set between 0.4 to 1.0 pl, allowing for a margin of error, the contrast between the image recorded by the large outlets 100a and the small outlets 100d is maintained and the discharge characteristics for each nozzle is stabilized

regardless of the length of the ink channels.

A recording head according to an embodiment, as described above, may be mounted on a typical printing apparatus for inkjet recording. Furthermore, the recording head may be mounted on a copy machine, a facsimile machine including a communication system, a word processor including a printing unit, or an industrial recording apparatus combined with various processors. The above-mentioned typical printing apparatus may include, for example, a conveying unit for conveying a recording medium, a head-holding unit for holding a recording head so that outlets oppose the recording medium and for reciprocatingly scanning the recording medium in the width direction (i.e., the direction orthogonal to the conveying direction), and a controlling unit for driving the conveying unit and the head-holding unit.

The recording head according to this embodiment is not limited to a recording head configured to discharge ink for recording and may include a liquid discharge head configured to discharge liquid using heating resistors included in recording elements.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest

interpretation so as to encompass all modifications, equivalent structures and functions.

This application claims priority from Japanese Patent Application No. 2004-326781 filed November 10, 2004, which is hereby incorporated by reference herein.